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ALKALI-SILICA REACTION IN CONCRETE FROM HIWASSEE DAM, NORTH CAR--ETC(U)
AUG 78 A D BUCK, J P BURKES

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by

(10) Alan D. Buck, Jerry P. Burkes

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Concrete Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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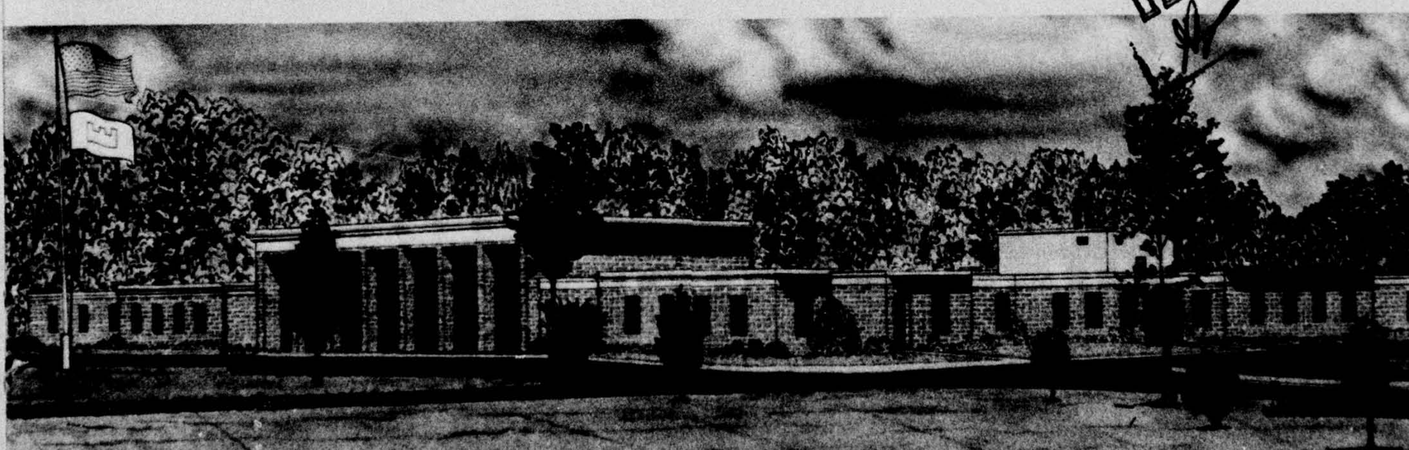

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The TVA requested a petrographic examination of concrete cores from Hiwassee Dam to determine whether an alkali-silica reaction had occurred. There is substantial cracking of the concrete in the dam and such a reaction could be responsible for the cracking. Construction of Hiwassee Dam was completed in 1940, so the concrete is over 38 years old. Signs of alkali-silica reaction were found in the top and bottom portions of two 6-in.-diam cores taken from the dam. The main signs of the reaction were white alkali-silica gel in some

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20. Abstract (Continued)

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voids, on old broken surfaces or at aggregate-paste contacts, and the presence of reaction rims on many particles of the brown quartzite. Some cracking of aggregate and paste was also detected.

The presence of this reaction does not automatically prove it was the cause of the cracking in the concrete, but it would seem to be a reasonable assumption that it was one cause of the cracking since no other evidence of potentially deleterious chemical or physical damage was found. This conclusion is based on laboratory observation only.

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PREFACE

This work was funded by the Tennessee Valley Authority (TVA). They agreed to permit wider distribution of the report to make the information more readily available. Questions on the engineering behavior of the dam should be referred to Mr. G. H. Kimmons, Manager of Engineering, Design and Construction, TVA, Knoxville, TN.

Funding for issuance of this report was provided by the Concrete Technology Information Analysis Center (CTIAC). This is CTIAC report No. 32.

COL John L. Cannon, CE, was Commander and Director of the U.S. Army Engineer Waterways Experiment Station when the work was done. Mr. F. R. Brown was Technical Director.

Contents

Conversion Factors, U. S. Customary to Metric (SI) Units of Measurement

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
degrees (angular)	0.01745329	radians
feet	0.3048	metres
inches	25.4	millimetres

Corps of Engineers, USAE Waterways Experiment Station	Petrographic Report	Structures Laboratory P. O. Box 631 Vicksburg, Mississippi
Project Examination of Two Concrete Cores, Hiwassee Dam		Date 11 May 78 ADB, PB

Background

1. The TVA requested a petrographic examination of concrete cores from Hiwassee Dam to determine whether an alkali-silica reaction had occurred. There is substantial cracking of the concrete in the dam and such a reaction could be responsible for the cracking.

Samples

2. Portions of two 6-in. diameter concrete cores from Hiwassee Dam were received 14 March 1978. They are identified below:

Core No.	Center Line of Block	Description
1	8	Taken normal to sloping downstream face of dam; consists of two pieces from depths of 0.0 to 3.0 ft and two pieces from 9.1 to 10.9 ft.
2	5	Vertical core from sloping downstream face of dam; consists of two pieces from 0.0 to 3.0 ft, one piece from 7.7 to 8.7 ft, and one piece from 11.0 to 12.0 ft.

A 1-1/2-in. diameter core had been taken from these cores earlier.

Test procedure

3. The pieces of each core were inspected and logs were made. The top and bottom piece of each core was sawed along its longitudinal axis. The sawed surfaces were inspected. Samples were then taken from these pieces as follows:

a. An area from each of these pieces was ground smooth and examined with a stereomicroscope. One of these surfaces was photographed.

b. Portions of these pieces were broken and the broken surfaces were examined with a stereomicroscope.

c. A sample of white alkali-silica gel was obtained from a void at about the 1 ft depth of piece 1 of core 2. Part of it was ground and examined by X-ray diffraction. Other parts of it were examined as powder immersion mounts with a polarizing microscope. Similar looking gel from other parts of the cores was also examined as powder immersion mounts.

d. Four thin sections were made from freshly sawed surfaces cut parallel to the earlier cuts and were examined with a polarizing microscope.

e. Small cores of both types of coarse aggregate were obtained from these pieces. Each of these samples was ground to pass a 45-μm sieve (No. 325); they were examined by X-ray diffraction as back-packed specimens to minimize preferred orientation.

f. A concentrate of cement paste was prepared from piece 1 and from piece 4 of core 2. They were ground to pass a 45-μm sieve (No. 325) and were examined by X-ray diffraction.

4. The X-ray patterns were made with an X-ray diffractometer using nickel-filtered copper radiation.

Results

5. As stated, the near surface parts of two concrete cores and a couple of feet of sample from the 7-to-12-ft-depth interval from the same two cores were received. Figures 1 and 2 show logs of these cores. They represent nonair-entrained mass concrete containing 6-in. maximum-sized aggregate. When it was noted that the coarse aggregate in these two cores resembled that in cores from Fontana Dam that was examined here in 1974, and that evidences of alkali-silica reaction were similar, a good deal of the present examination was based on that earlier work.[1] It is reasonable that the aggregate in both projects be similar since Moneymaker[2] reported the rocks at both sites to belong to the Pre-Cambrian Great Smoky Formation consisting of micaceous quartzite (in part conglomeratic); quartz-biotite schist; and mica schist, at Hiwassee; and of conglomeratic quartzite and phyllite of the same formation at Fontana. Reference 3 indicates that the Hiwassee aggregate was quarried on the site and was composed of graywacke derived from quartz-feldspar-ferromagnesian sand with varying quantities of mica. This is apparently the same rock as that Moneymaker[2] mentioned. Reference 4 also provided general information on several TVA projects. However, none of the references found provided any data on alkali contents of the cements used at Hiwassee. Apparently they were not determined, which is not surprising considering the dates of construction.

6. The coarse aggregate in these cores consisted largely of partly micaceous brown conglomeratic rock and some particles of fine-grained black rock. The fine aggregate was the same material. While the brown rock is probably metamorphosed subgraywacke[1] it will be referred to as quartzite (brown) and schist (black) in this report to abide by Moneymaker's earlier names.[2]

7. Evidence of alkali-silica reaction was common. It was seen as reaction rims on many of the quartzite particles (Photo 1). Similar rims were not noted on the schist but were probably present. Reaction rims on black rocks can be almost impossible to detect. Small spots of white alkali-silica gel were seen on core surfaces, on old broken surfaces, and on freshly broken surfaces. Powder immersion mounts of the gel showed it to be the salt and pepper type with its refractive index between 1.470 and 1.482. Some of it

was the clear type with first-order gray interference color, or was amorphous with refractive index below 1.544. This gel is similar to that found in the Fontana cores.[1] The X-ray diffraction pattern of the gel sample showed spacings as follows:

A*	Estimated Intensity
12.1	very strong
10.1	very weak
8.6	very weak
6.6	weak
6.1	weak
5.0	very weak
3.6	weak
3.5	very weak
3.0	weak
2.9	medium
2.8	weak
2.3	very weak
2.2	very weak
2.1	very weak
1.7	weak

* A times 10^{-1} = nanometres.

The 10.1 and 5.0 spacings may be due to mica contamination; the 3.0 spacing may be due to calcite in part. The gel spacings show some similarities to the Fontana gel spacings.[1] As with those spacings, the present ones were not identified. This inability to identify X-ray diffraction patterns of alkali-silica gels is the subject of work by Buck and Mather.[5]

8. Other evidence of alkali-silica reaction included cracks found on ground surfaces in the mortar, in aggregate particles, or connecting them. Some cracks were also present in the thin sections, and the paste was usually carbonated along these cracks, which suggested they were old.

9. Study of the thin sections showed, as usual, that aggregate reaction rims were not detectable in plane or polarized light. Calcium hydroxide was present and relatively large residual cement grains were common. Calcium hydroxide appeared to be lower than normal in some areas. All of the aggregate in the thin sections was the brown quartzite type. It consisted of quartz, mica, some plagioclase, and in some pieces calcite. Most of the mica was biotite with smaller amounts of muscovite. The rock texture was principally anhedral fine quartz grains with sutured grain contacts. Occasional larger grains were present. X-ray diffraction patterns of three pieces of each rock type showed scattered potassium feldspar, pyrite, and the probable presence of a little clay in addition to the minerals seen in thin section. Overall, there were no significant differences in composition in the two rock types by X-ray diffraction. The same result was found in the Fontana cores.

10. The X-ray patterns of the paste concentrates were largely of rock since it had been impossible to remove the aggregate fines. There were also small amounts of ettringite, calcium hydroxide, and calcium monocarboaluminate present as normal cement hydration products. One unusual feature was the presence of a weak X-ray peak at 12.3 to 12.4 A. This could indicate the presence of a small amount of alkali-silica gel in the cement paste. While the gel was fairly common in the concrete the other observations had not indicated enough present to be expected to show in these X-ray diffraction patterns. This peak could also be the long spacing of calcium silicate hydrate I, but its presence in so well crystallized a form in cement paste would be most unusual. The identification and significance of this long X-ray spacing in the paste concentrates was not determined.

11. Comparison of thin sections, of X-ray diffraction patterns of aggregates, and of paste concentrates with those from the Fontana samples[1] indicated general similarities. However, the long X-ray spacing was not found in the X-ray patterns of the Fontana[1] paste concentrate.

Discussion

12. Construction of Hiwassee Dam was completed in 1940[3] so this concrete is over 38 years old. Signs of alkali-silica reaction were found in the top and bottom portions of both cores examined here. The main signs of this reaction were white alkali-silica gel in some voids, on old broken surfaces or at aggregate-paste contacts, and the presence of reaction rims on many particles of the brown quartzite (Photo 1). Some cracking of aggregate and paste was also detected.

13. While reaction rims on aggregate particles are more apparent in the Hiwassee concrete and alkali-silica gel may be more abundant in the Hiwassee than in the Fontana concrete, the materials used and the manifestations of alkali-silica reaction in the two structures indicate the same reaction in both structures.

14. The presence of this reaction does not automatically prove it was the cause of the cracking in Hiwassee concrete, but it would seem to be a reasonable assumption that it was one cause of the cracking since no other evidence of potentially deleterious chemical or physical damage was found. This conclusion is, of course, based on laboratory observation only.

Summary

15. Petrographic examination of parts of two concrete cores from Hiwassee Dam has shown the presence of alkali-silica reaction. This reaction appears to be similar to that described for Fontana Dam in 1974.[1]

References

1. Petrographic report dated 3 May 1974, subject: Examination of Fontana Dam Concrete Core, Concrete Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

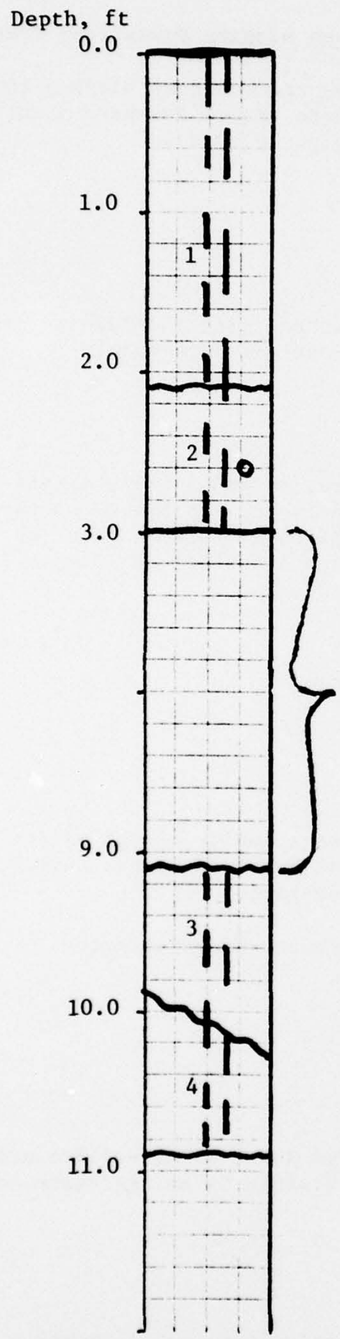
2. Burwell, E. B., Jr., and Moneymaker, B. C., "Geology in Dam Construction," pp 41-43, in Applications of Geology to Engineering Practice, Geological Society of America Berkey Volume, 1950.

3. "The Hiwassee Project," TVA Technical Report No. 5, Vol 1, p 332, U. S. Government Printing Office, 1946.

4. "Concrete Production and Control," TVA Technical Report No. 21, U. S. Government Printing Office, 1947.

5. Buck, A. D., and Mather, Katharine, "Alkali-Silica Reaction Products from Several Concretes: Optical, Chemical, and X-Ray Diffraction Data," to be presented at 4th International Conference on the Effect of Alkalies in Cement and Concrete at Purdue University, W. Lafayette, Ind., June 1978.

Log of 6-in. Diameter TVA Concrete Core No. 1
from Center Line of Block 8,
Hiwassee Dam



Top is formed surface.
Drilled normal to sloping downstream face at el 1476.5 ft.
There is an open crack across the top of the core that can be traced downward about 1 in.

Old break

Core contains a 1-1/2-in. diameter vertical core hole. Five spots of white alkali-silica gel detectable on surfaces of pieces 1 and 2.

Steel

Sawed surface

No core sample received

Fresh broken surface. Spot of white alkali-silica gel on this surface.

6-in. coarse aggregate.

Fresh break along aggregate surface.

Old break--partially along aggregate surface.

Vertical scale: 1 square = 0.2 ft

Figure 1

Log of 6-in. Diameter TVA Concrete Core No. 2
from Center Line of Block 5,
Hiwassee Dam

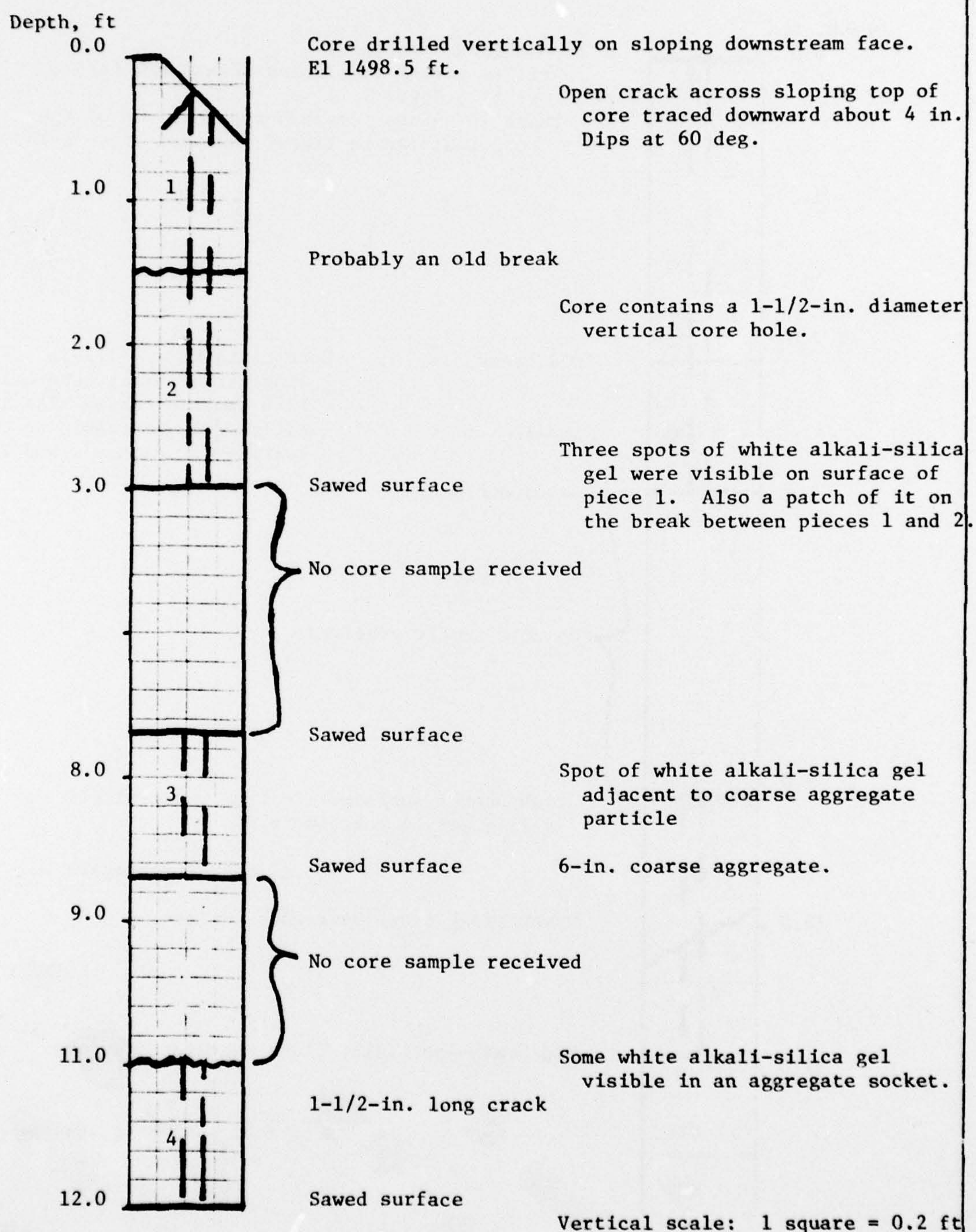
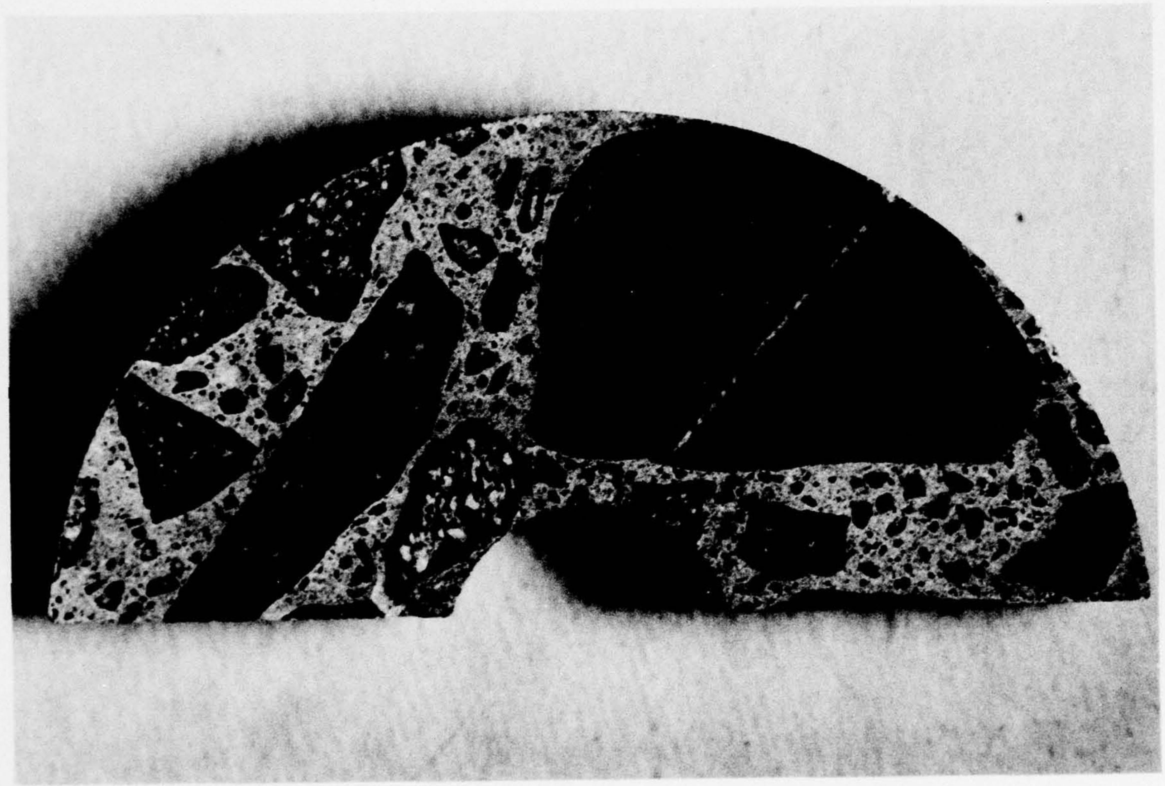


Figure 2



Photograph 1. Portion of sawed and ground horizontal surface from core 2, block 5, piece 4, at about 11.5-ft depth, X1. All of the coarse aggregate is the brownish type and practically every piece has a reaction rim.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

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  CTIAC Report No. 32.
  References: p. 8.

1. Alkali aggregate reactions. 2. Concrete cores. 3. Concrete cracking. 4. Concrete dams. 5. Hiwassee Dam. I. Burkes, Jerry P., joint author. II. Tennessee Valley Authority. III. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; C-78-10.
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